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EDITORIAL

How to use facemask noninvasive ventilation

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Noninvasive ventilation (NIV) allows application of positive airway pressure without the need for endotracheal intubation. The main advantage of NIV is to provide respiratory support while avoiding the detrimental effects associated with invasive mechanical ventilation, sedation and paralysis. The facemask is the most used interface to deliver NIV. In the acute care setting, this technique was initially proposed to treat patients with acute hypercapnic respiratory failure due to chronic obstructive pulmonary disease exacerbation [1]. From late 1990s, NIV has been applied to manage patients in diverse clinical settings [2].

Set-up and ventilatory settings

In the acute setting, facemask NIV is usually administered through an oronasal or a full-face interface, with similar efficacy. Facemasks are designed to create an airtight seal and are equipped with adjustable straps and cushioning to enhance patient comfort and improve compliance during prolonged use (Fig. 1).

Although facemask NIV is usually delivered through a bi-tube circuit connected through a Y-piece to a gas-compressed or turbine ventilator, single-limb circuits with intentional leaks can be used with similar efficacy. Gas conditioning is needed, except when low FiO_2 is delivered with turbine-driven ventilators. Heat and moisture exchangers and heated humidifiers have similar efficacy in terms of clinical outcome. However, heated humidifiers are more effective in heating and humidifying the inspired gas, especially in case of significant air leaks, and provide physiological advantages by enhancing CO_2 clearance and minimizing work of breathing [3].

Ventilators are conventionally set in the pressure-support mode, with positive end-expiratory pressure (PEEP) ranging between 5 cmH_2O and 8 cmH_2O or higher (e.g., obese patients). In patients with obstructive disease, PEEP levels should be titrated to facilitate effective triggering. Pressure support should balance the need for adequate assistance with the risks of overassistance, that include worsening hyperinflation in obstructive patients and large tidal volumes with progression of lung injury in hypoxemic patients. One approach is to set the minimal pressure support to obtain a tidal volume of 6–8 ml/kg of predicted body weight with clinically acceptable respiratory rate. Inspiratory (2 l/min) and expiratory triggers (20–50% of peak inspiratory failure) are set to optimize patient-ventilator interaction. Rise time also needs to be adjusted to maximize patients' comfort, usually needing to be shorter in patients with obstructive disease, but never at the minimum value [4]. Modern ventilators are equipped with NIV-dedicated software foreseeing leak compensation algorithms and a time-regulated cycling off criterion (1–1.2 s), which enables expiratory cycling even in case of significant leaks.

Indications

In acute hypercapnic respiratory failure ($PaCO_2 > 45$ mmHg with $pH < 7.35$), pressure support unloads respiratory muscles, increases minute ventilation and reduces respiratory rate, therefore limiting dynamic hyperinflation. A low level of PEEP (5 cmH_2O) counteracts intrinsic PEEP and minimizes the isometric workload required to generate the inspiratory flow [1]. Clinically, facemask NIV quickly reverses hypercapnia and acidosis, thus reducing the need for intubation and improving short and long-term clinical outcomes [5]. Under strict clinical monitoring, a trial of NIV should also be considered in patients with hypercapnia-induced altered consciousness secondary to chronic obstructive pulmonary disease exacerbation. This practice, however,

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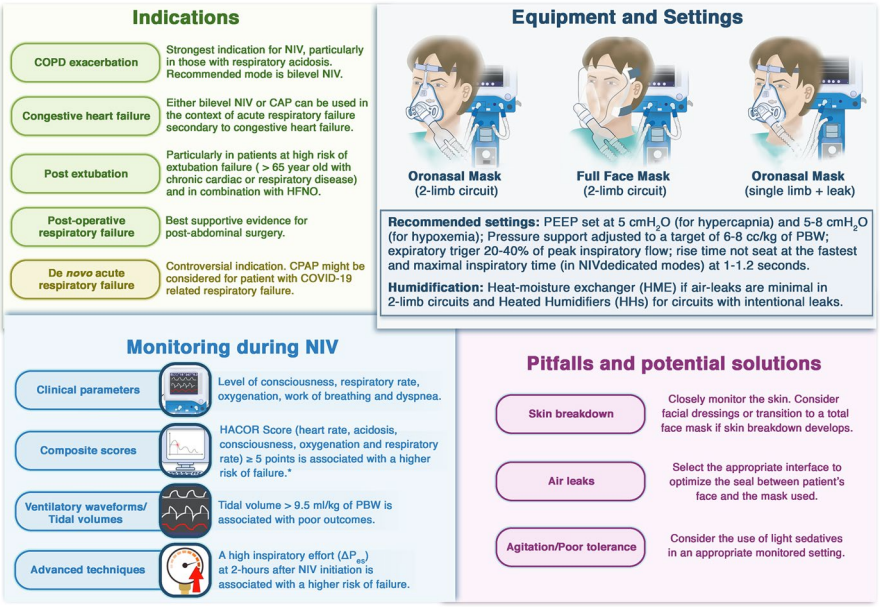
Indications
COPD exacerbation
Strongest indication for NIV, particularly in those with respiratory acidosis. Recommended mode is bilevel NIV.
Congestive heart failure
Either bilevel NIV or CAP can be used in the context of acute respiratory failure secondary to congestive heart failure.
Post extubation
Particularly in patients at high risk of extubation failure (> 65 year old with chronic cardiac or respiratory disease) and in combination with HFNO.
Post-operative respiratory failure
Best supportive evidence for post-abdominal surgery.
De novo acute respiratory failure
Controversial indication. CPAP might be considered for patient with COVID-19 related respiratory failure.
Equipment and Settings
Oronasal Mask
(2-limb circuit)
Full Face Mask
(2-limb circuit)
Oronasal Mask
(single limb + leak)
Recommended settings: PEEP set at 5 cmH2O (for hypercapnia) and 5-8 cmH2O (for hypoxemia); Pressure support adjusted to a target of 6-8 cc/kg of PBW; expiratory triger 20-40% of peak inspiratory flow; rise time not seat at the fastest and maximal inspiratory time (in NIVdedicated modes) at 1-1.2 seconds.
Humidification: Heat-moisture exchanger (HME) if air-leaks are minimal in 2-limb circuits and Heated Humidifiers (HHs) for circuits with intentional leaks.
Monitoring during NIV
Clinical parameters
Level of consciousness, respiratory rate, oxygenation, work of breathing and dyspnea.
Composite scores
HACOR Score (heart rate, acidosis, consciousness, oxygenation and respiratory rate) ≥ 5 points is associated with a higher risk of failure.*
Ventilatory waveforms/ Tidal volumes
Tidal volume > 9.5 ml/kg of PBW is associated with poor outcomes.
Advanced techniques
A high inspiratory effort (ΔPes) at 2-hours after NIV initiation is associated with a higher risk of failure.
Pitfalls and potential solutions
Skin breakdown
Closely monitor the skin. Consider facial dressings or transition to a total face mask if skin breakdown develops.
Air leaks
Select the appropriate interface to optimize the seal between patient's face and the mask used.
Agitation/Poor tolerance
Consider the use of light sedatives in an appropriate monitored setting.

Fig. 1 Summary of the main indications, needed equipment, suggested settings, monitoring tools for using facemask NIV in the intensive care unit. *COPD* chronic obstructive pulmonary disease; *CPAP* Continuous positive airway pressure; *HFNO* high flow nasal oxygen; *NIV* noninvasive ventilation; *PEEP* positive end-expiratory pressure

does not apply to patients with acute asthma exacerbations [6].

In patients with respiratory failure due to cardiogenic pulmonary edema, facemask NIV increases lung volume, reduces pulmonary shunt, respiratory rate, inspiratory effort and right ventricular preload, favors myocardial contraction and reduces left ventricle afterload. Both facemask NIV and continuous positive airway pressure (CPAP) have demonstrated to be effective therapies in patients with acute respiratory failure due to cardiogenic pulmonary edema, associated with a lower risk of treatment failure and improving clinical outcomes [5].

In patients with de novo acute hypoxemic respiratory failure and/or acute respiratory distress syndrome (including immunocompromised), the role of facemask NIV is controversial. Facemask NIV can improve oxygenation but does not reduce the rate of endotracheal intubation in patients with most severe hypoxemia ($PaO_2/FiO_2 < 200$ mmHg), in whom it can even end up increasing mortality [7]. Despite patients who avoid endotracheal intubation show good clinical outcomes, the rate of treatment failure is high (30–60%) and patients who require intubation after receiving NIV are burdened by an increased risk of death [8], possibly because of the occurrence of self-inflicted lung injury. Accordingly, most recent guidelines suggest that a trial of facemask NIV can be considered, but requires careful clinical monitoring aimed to avoid delays in endotracheal intubation and protective ventilation [9]. In these patients, other techniques as high-flow nasal oxygen and helmet NIV represent promising alternatives. Despite the controversial evidence of face-mask NIV during de novo acute hypoxemic respiratory failure, face-mask CPAP has been shown to decrease the risk of intubation or mortality (composite outcome) compared to standard oxygen in patients with acute respiratory failure due to coronavirus disease 2019 (COVID-19) [10].

Facemask NIV is an effective strategy for patients experiencing acute respiratory failure following cardiothoracic and abdominal surgery. It reduces atelectasis, potentially decreasing bacterial growth and mitigating bacterial translocation, finally limiting the development of postoperative pneumonia and reducing the rate of endotracheal intubation [11].

In the post-extubation period and among patients at high-risk of extubation failure (i.e., older than 65 years old and underlying chronic cardiac or lung disease), preemptive facemask NIV, combined or not with high-flow nasal oxygen, reduces re-intubation rate and may improve clinical outcomes, particularly in obese patients [12–14]. The evidence regarding the use facemask NIV for patients who develop respiratory failure after extubation in the intensive care unit is scarce [15]: one classical study indicates that this intervention is potentially associated with harm due to delayed intubation [16], but recent data seem to question this hypothesis [17].

Monitoring

The main goal of monitoring during NIV is to assess the response to treatment, to adjust ventilator settings and, most importantly, to identify patients that might rather benefit from transition to invasive ventilation. Because of the risks related to delays in endotracheal intubation, this is particularly relevant when NIV is used in acute hypoxemic respiratory failure. Although no formal criteria for certifying the need for invasive ventilation are validated, lack of improvement in oxygenation, worsening dyspnea and persistently high respiratory rate are signs of treatment failure. Of note, respiratory rate as an isolated parameter is an unreliable marker of inspiratory effort and respiratory distress, and the clinician should also consider other parameters [18]. The HACOR score, which includes heart rate, acidosis, consciousness, oxygenation, and respiratory rate, was found to predict treatment failure early after NIV start (1–6 h) [19]. When patients with $PaO_2/FiO_2 < 200$ receive facemask NIV, an expired tidal volume exceeding 9.5 mL/kg of predicted body weight, which reflects high inspiratory effort and therefore increased risk of self-inflicted lung injury, is strongly associated to treatment failure and should prompt endotracheal intubation [20]. Accordingly, persistently intense inspiratory effort (> 10–15 cm H_2O), measured through esophageal manometry early after NIV initiation, suggests high risk of NIV failure [21]. Because esophageal manometry is not feasible for all patients, studies to identify noninvasive alternatives for inspiratory effort assessment are underway. In the absence of leaks, high P0.1 (> 3–4 cmH_2O) suggests presence of intense respiratory drive with respiratory distress [22].

Limitations

The primary constraint associated with delivering NIV through a face-mask is the occurrence of significant air leaks, stemming from an insufficient seal between the patient's face and the applied mask. These leaks contribute to patient–ventilator asynchronies, elevate the risk of treatment failure, and imped the effective delivery of noninvasive positive pressure. Ensuring an optimal fit between the mask and the patient's face, coupled with vigilant leak monitoring, is a cornerstone of successful NIV application.

Skin breakdown, notably in the nasal bridge area, is a common complication, affecting up to 20% of patients undergoing NIV with a face-mask. When applied for prolonged periods, face-mask NIV may impede adequate nutrition, as oral feeding poses a risk of aspiration, and the insertion of a nasogastric tube may establish or exacerbate leaks between the skin and the mask. Gastric distension and impaired secretion clearance are also important limitations in the use of noninvasive ventilation. These challenges often lead to frequent treatment interruptions, particularly troublesome during prolonged NIV deployment, thereby restricting its utility in this setting.

One approach to enhance comfort and tolerance involves interchangeably employing oronasal and full-face masks within the same patient. Additionally, the consideration of light sedation, such as dexmedetomidine or opioids, has been explored, showing potential benefits in mitigating treatment-associated challenges [23].

One final limitation of the facemask is the impossibility to apply high levels of PEEP, which may be beneficial limit the risk of self-inflicted lung injury and exert all the putative benefits of the technique in acute hypoxemic respiratory failure [24]. Other interfaces or strategies may serve this aim in this specific subgroup of patients.

Contraindications

Noninvasive ventilation must not be administered to patients who urgently require intubation, including those facing imminent cardiac or respiratory arrest or those with airway obstruction, inadequate secretion clearance, and facial deformities that hinder the proper fitting of a facemask also necessitate careful consideration.

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Author contributions

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Conflicts of interest

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